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DEVELOPMENT OF RESEARCH ON DSS META-DESIGN METHODOLOGY

Abstract: One of the ways that meta-design methodology, introduced into the DSS area by Moore and Chang, can be further advanced thanks to the DSS architecture approach. The seminal Sprague-Carlson DSS design paradigm (Data-Dialog-Modeling) underlies or underpins most discussions of DSS architectures. Research done by the authors for several Polish business enterprises in the 1980s indicated the need to extend the Sprague-Carlson architecture. Their proposed solution thus seeks to enhance the original meta-design DSS methodology. The paper aims to present the findings of the authors' research efforts focusing on a solution which has been in effect for over a decade in large enterprises as well as in capital groups.

Keywords: DSS, DDM paradigm, meta-design methodology, software architecture, case study approach.

1. Introduction

Klein & Methlie were among the first scholars to emphasize the importance of knowledge development on both sides of the man-computer dialog in decision support systems (DSS): "a well-designed DSS is the one which speeds up the learning process of the user" [Klein, Methlie 1995]. It is a natural property of knowledge that it evolves continuously, therefore unless a DSS is capable of evolving with the knowledge, it soon lags behind and its benefits are lost.

Just like the decision making process itself, the decision context changes dynamically in the course of decision making. Realizing these DSS characteristics, researchers called for the development of DSS meta-methodology: "the classic MIS development life-cycle approach is insufficient as a prescriptive guide for building DSS [since it] (…) does not lay out a step-by-step procedure or even an exhaustive list of topics (…) We synthesize ideas from existing DSS design frameworks to produce a meta-design methodology from which individual DSS designers can develop their own design frameworks, appropriate to their particular needs [Moore, Chang 1983]".

The meta-design approach had its advocates who undertook to further develop it [cf. Stanek 1999; Hevner, Hatterjee 2010; El-Gayar, Deokar, Tao 2013]. Due to the volatility and change dynamics of the design space, frequently coupled with a need for organizational change entailed by IT deployment, we see the ongoing integration of current trends in system design and organizational change [Fry 2009].

Meta-design methodology provides a higher-level abstract rules supporting the working methodology framework used in the DSS development process. Meta-design literature supplies a variety of such rules, some of which deserve to be underlined [Fischer, Giaccardi 2004; Fischer 2010]:

- developing socio-technical environments that support and empower users to engage in the process of system development not only at design time but also at use time,
- embodying the human ability of *autopoiesis* in projects for which the "designing the design" process is a first-class activity,
- supporting social creativity by providing the technical and social conditions for the exchange of ideas during workshops, discussions, debates, brainstorming, co-creation sessions and other forms of intense collaboration,
- combining art and design in the processes of self-realization,
- use of meta-analysis for comparing, combining, synthesizing, summarizing, specifying, and generalizing of previous studies.

In our development of DSS meta-design methodology, we have followed the software architecture approach. Dan Power [2004] perceives the following advantages of employing the architecture approach within DSS projects: better collaboration, easier planning, implementation and integration with other systems, and an augmented ability to evaluate technology. Clyde Holsapple, one of the fathers of the DSS concept, commented [Holsapple 2008] that "DSS architecture does not define what DSS is; rather, it functions as an ontology that gives a common language for design, discussion, and evaluation of DSS". This perspective on DSS corresponds with Lambert's opinion that "The architectural design should set a common level of understanding among technical, non-technical and management participants". Suresh Basandra [2013], on the other hand, believes that "System architecture is the process of partitioning a software system into smaller parts". The above insights bring us to Holsapple's [2008] definition of the DSS architecture: "DSS architecture is a general framework that identifies essential elements of a DSS and their interrelationships".

2. Overview of the DDMKCC architecture

Much of the discussion on DSS architectures has been founded on the seminal Sprague-Carlson design paradigm: Data-Dialog-Modeling. Recapitulating the paradigm, "The Encyclopedia of Decision Making and Decision Support Technologies" states that DSS must consist of three sets of capabilities belonging in the areas of dialog, data and modeling [*Encyclopedia*… 2008]. Even a very simplified picture such as that adapted from the "Encyclopedia…" (Figure 1) provides an important insight: the links between the model base and the data base make it possible to retrieve coefficients, parameters and variables from the database and record the outcomes of model computation in the database. These outcomes can then be used by other models later on in the decision making process. The distinction between data base, model base, and dialog generation management systems is also vital [Averweg 2008].

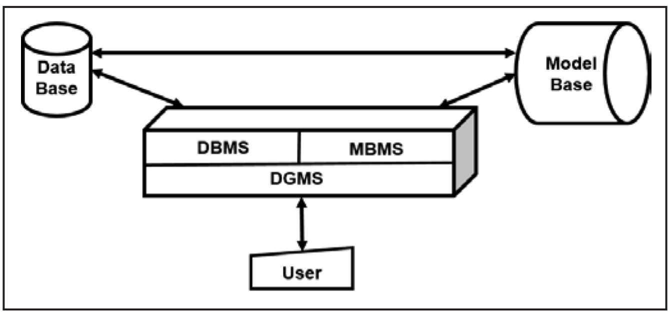


Figure 1. DSS components

Source: adopted from [Sprague, Watson 1996].

As a ramification of the DDM paradigm, the following architectures emerged providing for the integration of the three components: network DSS, bridge DSS, sandwich DSS, and tower DSS [Sprague, Carlson 1982]. It is interesting to note that more general architectures are used as patterns for producing specific/derivative architectures, nested in one another much like Russian *matryoshka* dolls. Examples of meta-analysis include: communication [cf. Power 2002; Bobosatu, Duta 2010], sensors and negotiations support [Vahidov, Kersten 2004; Vahidov 2007], use of UML [Fanti et al. 2012].

Substantial research work conducted by the authors for several Polish business enterprises[1] in the 1980s indicated the need to extend the Sprague-Carlson architecture. Their proposed solution includes six, rather than three, components (see Figure 2): (1) data, (2) dialog, (3)modeling, (4) knowledge, (5) communication and (6) creativity.

[1] Including RYFAMA Rybnik, ZPO Bytom, TELMED Zabrze, Stalexport Katowice, Huta Zygmunt Bytom.

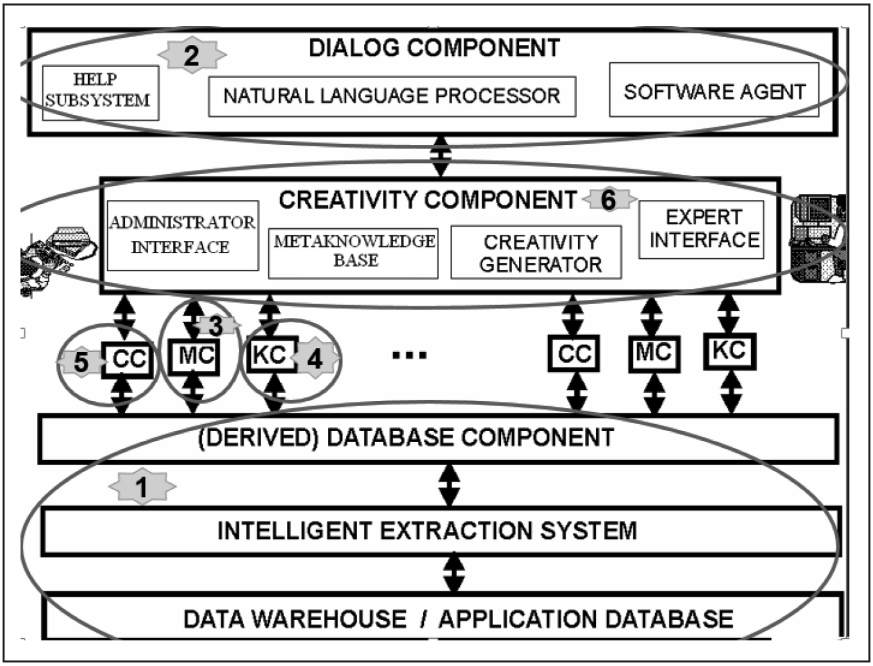


Figure 2. DDMKCC architecture

Source: [Stanek 1999].

2.1. DDM

The first three components have already been mentioned. The existing evolution trends include:

- Innovative solutions (data fusion, BI) to produce new DSS characteristics, such as in situational awareness, cognitive bias, etc.
- Interface agent (personal assistant, avatar) technology and ergonomic design of the dialog between the user and the system as a challenge for the user interface subsystem.
- Combining heterogeneous models (a hybrid model) in such a way that their concerted actions increase overall applicability and produce synergy (1 + 1 = 3).

2.2. DDMK

In existing and sustainable systems, the control function is performed via meta-knowledge subsystems (like norms, axioms, ontologies). The development of a meta-knowledge subsystem is driven by the double loop pattern of knowledge development. The primary feedback loop, which is characteristic of adaptive learning, involves detection and rectification of deviations from operational norms.

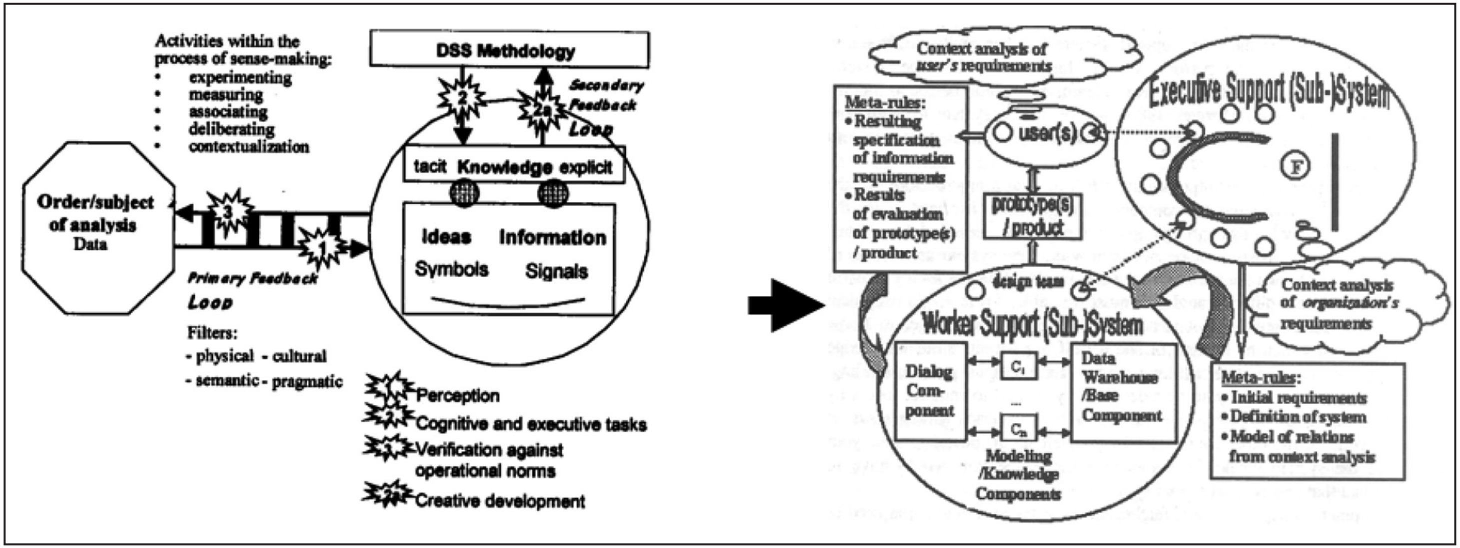


Figure 3. The double loop pattern of knowledge development in/for DSS

Source: [Stanek 1998; Stanek, Sroka 2000].

The secondary loop (2a), found in so-called generative learning, is responsible for the creative modification of operational norms (cf. Figure 3, left).

The more specific picture (Figure 3, right) distinguishes between two types of managerial activities – decision making and leadership. The actual support system, called Worker Support System, is an open system capable of operation on meta-rules supplied by the empowerment system called the Executive Support System. Three kinds of meta-rules have been isolated: initial requirements, system definition, and models of relations. The novelty of our approach is in that the Executive Support System provides a framework for the discussion on the Worker Support System and, from this viewpoint, is seen as a meta-system.

2.3. DDMKC

It is essential in any DSS project to thoroughly analyze interactions among stakeholders. "[Managers] are not seen as atoms (…) [but as] active, purposeful agents. … [I]t is possible to visualise the Decision Making Network (DMN) and to investigate what happens within the networks as the organization tackles a Decision Situation" [Adam 1996]. There are many specific solutions designed to support communication within DMNs, such as Web-based DSS [Power 2002], Cloud-based DSS [Marston et al. 2011], SOA-based DSS [Ren, Zhang 2013], which are overviewed in Figure 4 (including DDMC components only).

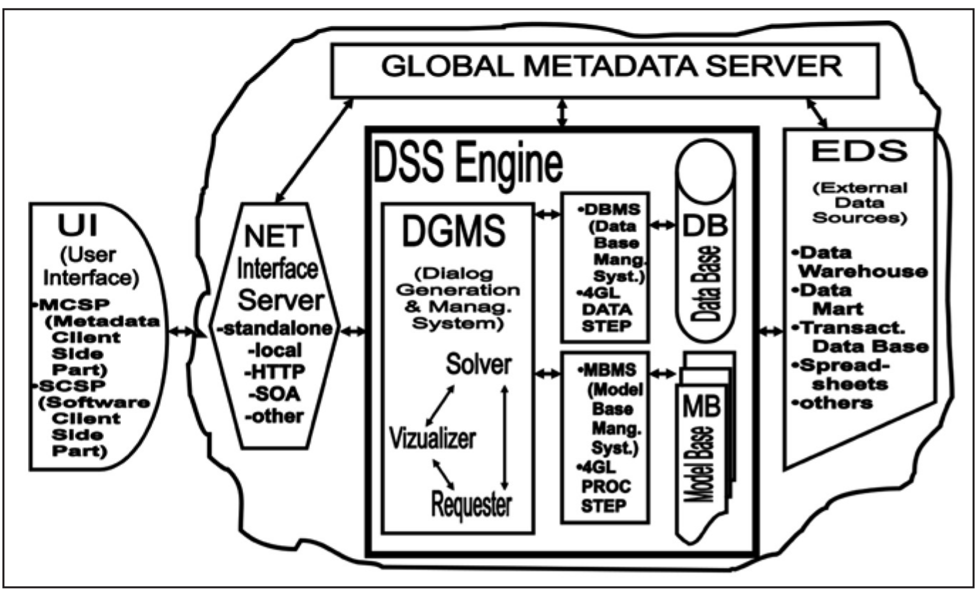


Figure 4. Solutions for network components

Source: [Stanek, Twardowska, Twardowski 2013].

2.4. DDMKCC

Early publications dealing with creativity highlighted the need for a DSS described as a right-brained decision support system. Initial fascination with right brain thinking was soon replaced by a more balanced approach insisting on the development of abilities which rely on the simultaneous participation of both hemispheres. In the area of support systems, this conviction is translated into a demand that DSS designers develop systems supporting the left and right brain thinking processes at the same time. The decision process combines a number of independent analytical, intuitive and critical operations in a manner resembling dance (cf. the model in Figure 5 – on the left).

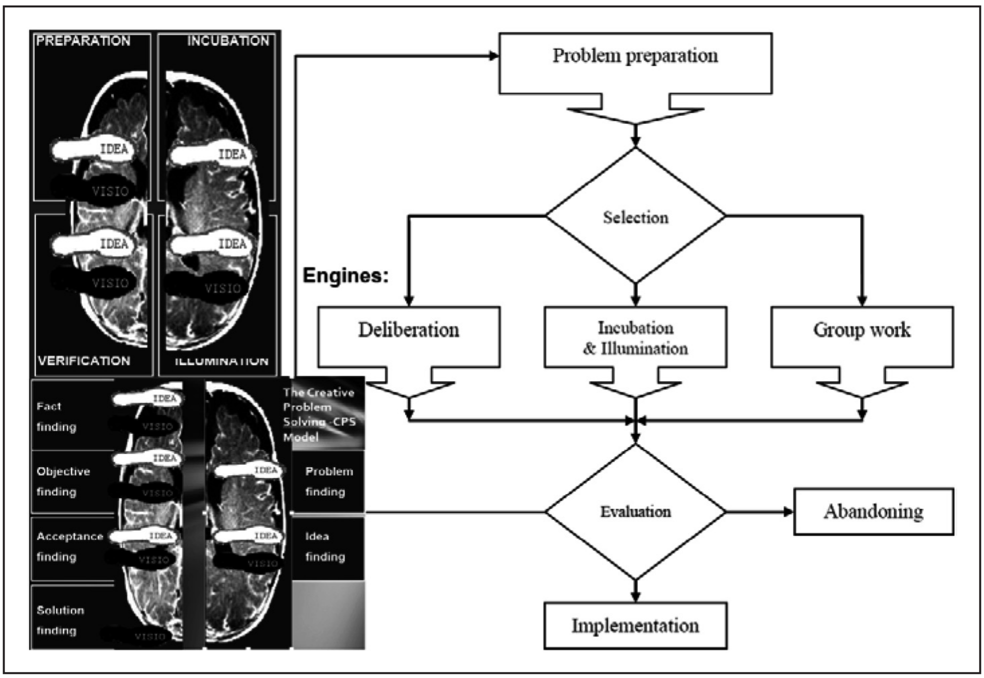


Figure 5. The new model of creativity

Source: based on [Stanek 2010].

The new research model of creativity support shown in Figure 5 (rightmost part) was crafted by blending the Wallas and the CPS models. Having prepared the problem, we move on to choosing the engine of our further creative efforts. Three engines are included in the preliminary version of the research model: deliberation, incubation and illumination, and teamwork.

3. Performance of DDMKCC model components – a study

We selected 10 out of the 200 implementation projects run in 2000-2012 by Consorg S.A. In this way, we arrived at a group of 10 business organizations from both the production and the services sectors which we deemed the most representative for our analysis and appraisal of the proposed approach – viz. its performance and practical effects. The sample included large enterprises as well as capital groups. Some of them were listed on the Warsaw Stock Exchange, while three of them (being international capital groups) had parent companies based outside Poland. Most of the companies operated in production industries. The average number of DSS users ranged from 5 to 10 advanced users and 20 to 30 novices or occasional users (see Table 1).

Table 1. The 10 selected business organizations from the manufacturing and services sectors

	Customer	Industry	Organization structure	DSS users	Project duration	Headquarters
1	2	3	4	5	6	7
1	Tauron Wytwarzanie (formerly Południowy Koncern Energetyczny S.A. [Southern Power Corporation]) Parent quoted on Warsaw Stock Exchange	power generation	one-layer capital group	50 primary users 150 other users	2000-2004	Katowice, Poland www.pke.pl
2	Vattenfall Heat Poland S.A. (Elektrociepłownie Warszawskie S.A.)	power generation	multi-layer capital group	25 primary users 20 other users	2002-2004 upgrade: 2009-2010	Warszawa, Poland (subsidiary) www.ewsa.com.pl
3	Odra Trans S.A.	inland navigation	multi-layer capital group, 20 subsidiaries (including a German based sub-group)	5 primary users 35 other users	implementation period: 2006-2007	Szczecin, Poland
4	Black Red White S.A.	furniture manufacturing	one-layer capital group, 30 subsidiaries	5 primary users 30 other users	2007-2008	Biłgoraj, Poland
5	Pradyż/Ceramika Paradyż sp. z o.o.	whiteware	no capital group	10 primary users 30 other users	2006-2008	Opoczno, Poland

Table 1, cd.

1	2	3	4	5	6	7
6	Cersanit S.A. Parent company quoted on Warsaw Stock Exchange	whiteware	multi-layer capital group, 40 subsidiaries (including a Russian based sub-group)	10 primary users 25 other users	2009-2010	Kielce, Poland
7	EC Będzin S.A. Listed on Warsaw Stock Exchange	heat generation	member (subsidiary) of RWE capital group	12 primary users	2009-2010	Będzin, Poland (subsidiary)
8	Kamis S.A. Listed on Warsaw Stock Exchange	food industry	no capital group	12 primary users 92 other users	2010-2011	Lubliniec, Poland
9	Lentex S.A. Parent company quoted on Warsaw Stock Exchange	chemical industry	one-layer capital group, 1 subsidiary		2010-2011	Poland
10	Paccor S.A./ Veriplast S.A.	food packaging	multi-layer capital group, 25 subsidiaries	5 primary users 45 other users	2010-2011	Luxembourg

Source: own elaboration.

Table 2. Decisions, tools and decision making models used within the DDMKCC model

Decisions	Capital groups	Other
Operational	• Consolidation of financial statements for external reporting (IFRS) • Financial monitoring and budgeting • Corporate supervisory activities • Cash flow planning and monitoring under cash-pooling models	• Operating budget planning and financial analysis • Cash flow analysis models • Pricing models
Tactical	• Simulations and financial monitoring using expert system reports • Benchmarking of functions and processes (diagnosing the causes of deviations in key performance indicators within capital group's strategy performance monitoring) • Models of asset allocation throughout the capital group	• Simulations and financial monitoring using expert systems reports • Benchmarking of the functions and processes of operating budget planning within the corporation's production units (diagnosing causes of deviations in key performance indicators) • Key investment project analysis models
Strategic	• Multi-dimensional simulations of capital sub-group structures; strategic and financial monitoring for management purposes • Value management models for capital groups	• EVA corporate value management models • BSC strategic management models • Strategic resource planning models

Source: own elaboration.

In all of the organizations, support was centered on decision making processes in the area of financial control. The solution was implemented in an effort to support decisions at all (operational, tactical, and strategic) management levels. At each level, a different set of analytical tools was offered, following the classification of models proposed by Turban and Aronson [2001] (see Table 2).

The distinct nature of capital group management was also reflected in specially tailored business models enabling decision support to be addressed at parent company level [Twardowski, Twardowska, Stanek 2009; Wartini-Twardowska, Twardowski 2009].

3.1. Data sources and data models

In the following discussion of the DDMKCC model's data component and its usage statistics, data sources and data models will receive separate treatment.

- Data sources

The taxonomy of data sources (cf. Table 3) was based on the classification proposed by Sprague and Watson [1996]. The findings of our observations and analyses are consistent with the widely known fact that, although data come from diverse sources, strategic decisions will involve the greater use of external sources and have less reliance on internal ones (e.g. ERP/MRP systems). The way corporate knowledge bases are exploited in making tactical decisions is notable, too. It is easy to see that relevant data are most commonly sourced from investment project analysis cases stored in archives, since such cases often provide valuable insights into how similar projects were evaluated in the past and offer analogies which can be instrumental in assessing the risk of new investments.

Table 3. Data sources for DDMKCC model

Decisions	Traditional ERP/MRP	Text processing and document processing systems; corporate knowledge bases	Open access data bases	Business information libraries; economic intelligence agencies
Operational	xxx	x	–	–
Tactical	xx	xxx	xx	x
Strategic	x	xx	xxx	xxx

Source: own elaboration.

- Data models component

Likewise, usage analysis of data models led us to believe that data warehouses are used the most when making strategic decisions (cf. Table 4), and that they are central to capital group management, particularly in groups that have not implemented a single transactional system. For them, a data warehouse can become an integrating

DSS component, unifying data and processes across the group. This corresponds to employing a data warehouse to support both operational and strategic decisions.

Interesting observations can be made in examining the use of multi-dimensional OLAP data structures in business decision making processes. When a well designed OLAP cube is combined with an ergonomic viewer, all of the reporting process can be handled via multi-dimensional structures, regardless of the type of decision to be made. It does not matter at all whether OLAP is embedded in a data warehouse or whether the multi-dimensional repository accesses transactional data directly. Obviously at the operational level, the application of OLAP technologies is limited to relatively simple (and repetitious) reporting. Advanced functionalities, on the other hand, such as those of data mining and hypothesis validation, are utilized at the other decision levels. By surveying the businesses from our sample, we were able to ascertain that wherever OLAP technology has been successfully implemented, reporting almost exclusively hinges on data supplied in this way, while other methods have been nearly abandoned.

Table 4. Data models employed within DDMKCC paradigm

Decisions	Relational data bases	Relational data bases – data warehouses	Multi-dimensional OLAP data base models	File system/ document repository
Operational	xx	xx	xxx	x
Tactical	x	xx	xxx	x
Strategic		xxx	xxx	xxx

Source: own elaboration.

3.2. Dialog and Communication components

The discussion of the dialog component's functionality will be broken down in a pattern proposed by Bennett for the assessment of DSS user interfaces: (1) knowledge base, conceived as a set of users' essential skills (knowledge) enabling them to work with the system, (2) command language, the way in which users operate the system, and (3) presentation language, i.e. the way in which output is represented[2].

- Knowledge base

Nearly every user highly appreciates the availability of complete system documentation, including operating instructions (cf. Table 5). Few, however, actually use it and, as a result, most of them require individual training. As long as it is fairly sufficient for users at the operational management level, those having to cope with less structured decision problems will normally need to have a good understanding

[2] http://dssresources.com (23 August 2013).

of the problem solving process and to be familiar with the applicable techniques. Without this know-how, users situated beyond the operational level might not be able to use the system resources efficiently; even if an expert system is activated to provide them with support in choosing the most suitable tools (models) for their problem, ultimately the choice has to be made by the user. Observation reveals that the most common reason why some systems are not used in tactical or strategic problem solving is not the technology itself, but the relatively high demand they put on users' competence (knowledge base).

- Command language

No matter what kind of problems are solved, the ability to communicate with the system via standard and context menus is usually taken for granted or seen as a minimum requirement concerning functionality. Individuals solving tactical problems in companies where an enterprise-wide data warehouse module has been implemented also insist on having the option of similar case finding in knowledge bases.

Table 5. The knowledge base of the DSS user interface within the DDMKCC model

Decisions	Interactive operation manual	Examples suited to user skill level	Support functions for system navigation	Problem solving skills training facility	Support options for user learning
Operational	xxx	x	xxx	x	x
Tactical	xxx	xxx	xx	xxx	x
Strategic	xxx	xx	x	x	xxx

Source: own elaboration.

Table 6. Use of command language functions in the DDMKCC model

Decisions	Standard system menu	Context menu	Data base query languages	Communication based on natural language processing	Knowledge base search for similar cases	Ability to guide user dialog toward problem resolution
Operational	xxx	xxx	xxx	–	–	–
Tactical	xxx	xxx	x	–	xxx	xx
Strategic	xxx	xxx	–	–	–	xxx

Source: own elaboration.

Users engaged in solving tactical and strategic problems will rather expect the system to become a "partner in problem solving". Interestingly enough, we found that the lowest skill levels are associated with the highest expectations from the system, including a proactive attitude in assisting the user. Conversely, the expectations of the most advanced and creative problem solvers are limited to being offered an efficient technology and a rich collection of presentation tools.

- Presentation language

Our survey demonstrated that users' expectations concerning the presentation language are closely tied with the mental model of the decision maker being the end user of information output by the system. For example, financial analysts working for top executives expect the presentation language to be as rich as possible and hence capable of satisfying the needs of any user without any further enhancements. The extent to which specific functions of the presentation language are used will vary largely depending on who uses the output information (e.g. corporate board members will have other preferences than line managers).

Table 7. Functions of the presentation language in the DDMKCC model

Decisions	Data and report presentation in a variety of forms – tables, text, presentation graphics	Report definition in terms of detail level and format of delivery (PDF, HTML, Word DOC, etc.)	Parallel work with multiple data sections, presentation in multiple forms using multi-window technology
Operational	xxx	x	x
Tactical	xxx	xxx	xx
Strategic	xxx	xxx	xxx

Source: own elaboration.

3.3. Knowledge and modeling components

Within the DDMKCC model, the knowledge component is defined as a resource comprising mathematical models and algorithms designed to transform data into information (deep knowledge) alongside heuristics used to support the decision making process (shallow knowledge) – rules, constraints, boundary conditions or any other information which may be generated within the DSS or acquired during the system's productive operation [Power 2002, p. 16]. This approach allowed us to perform a usage analysis of specific knowledge components vis-á-vis the type of decision problem. The findings provide important insights that can guide the further evolution of the DDMKCC paradigm.

First of all, addressing support to decision making processes at operational management level does not involve any major modifications to the pre-defined decision making models. These are typically simple cause-effect models focused on explaining deviations of actual performance from the plan. It is vital, nevertheless, that simulation and prediction functions be implemented in this class of models to enable "what if" and "what else" analysis (cf. Table 8).

Table 8. Functions of the presentation language within the DDMKCC model

Decisions	Pre-defined models embedded in DSS	Expandable pre-defined models	Custom model development and integration tools
Operational	xxx	x	–
Tactical	x	xxx	xx
Strategic	x	xx	xxx

Source: own elaboration.

The conclusions might be very different, however, if one looks at how the system supports strategic decision making processes. What is required of the system in such circumstances is, in the first place, adaptability and expandability through appending new decision models. The DSS not only has to offer the requisite tools to freely build decision models but also needs be able to instantly integrate (owing to two-way data interchange) with dedicated external systems handling specific business problems. (This would be necessary, for example, in a situation where an investment bank will not agree to open a long-term credit facility unless project performance is assessed and monitored using a model preferred by the bank.)

Secondly, the DDMKCC model includes a special resource containing knowledge on business processes utilized in decision making (decision workflows). Identifying the key business processes and analyzing the decision making processes intrinsic to them makes it possible to accumulate knowledge needed to discover and assess relationships between decisions and their outcomes. This appears critical, in the light of our research, for decision analysis at all levels – operational, tactical, and strategic (cf. Table 9).

Table 9. Functions of the presentation language within the DDMKCC model

Decisions	Mathematical models and algorithms	Workflow procedures	Heuristics driven by expert knowledge	Algorithms based on fuzzy expert rules
Operational	xxx	xxx	x	x
Tactical	xxx	xxx	xx	xxx
Strategic	x	xxx	xxx	x

Source: own elaboration.

Thirdly, our observations suggest that other than deterministic models are used relatively rarely. The most common approach is the one founded on deterministic scenario building techniques where the best and worst-case scenarios are identified. Where probabilistic models are used, preference is given to approaches based on subjective probability.

Table 10. Functions of the presentation language within the DDMKCC model

Decisions	Deterministic	Fuzzy	Probabilistic
Operational	xxx	x	–
Tactical	xxx	xx	–
Strategic	xxx	x	x

Source: own elaboration.

3.4. Creativity component

Our survey indicates that the most frequently used creative problem solving tools include:

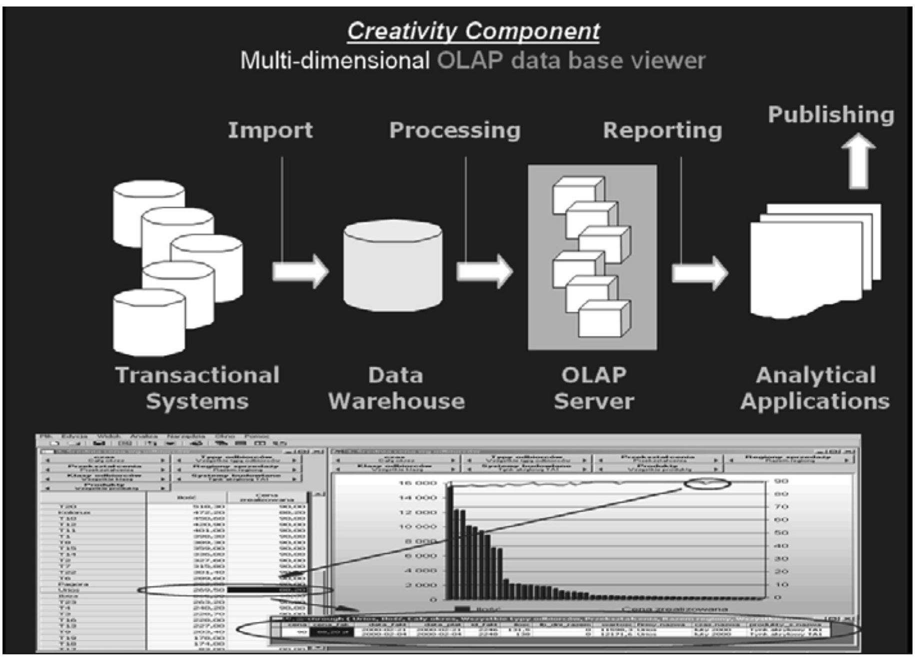


Figure 6. Multi-dimensional OLAP data base viewer

Source: own elaboration.

- context-sensitive help along with access to historical data and similar cases,
- a multi-dimensional OLAP data base viewer for convenient hypothesis testing during the creative problem solving process (Figure 6),
- group work support tools, such as dedicated discussion forums or widely popular instant messengers (Figure 7),

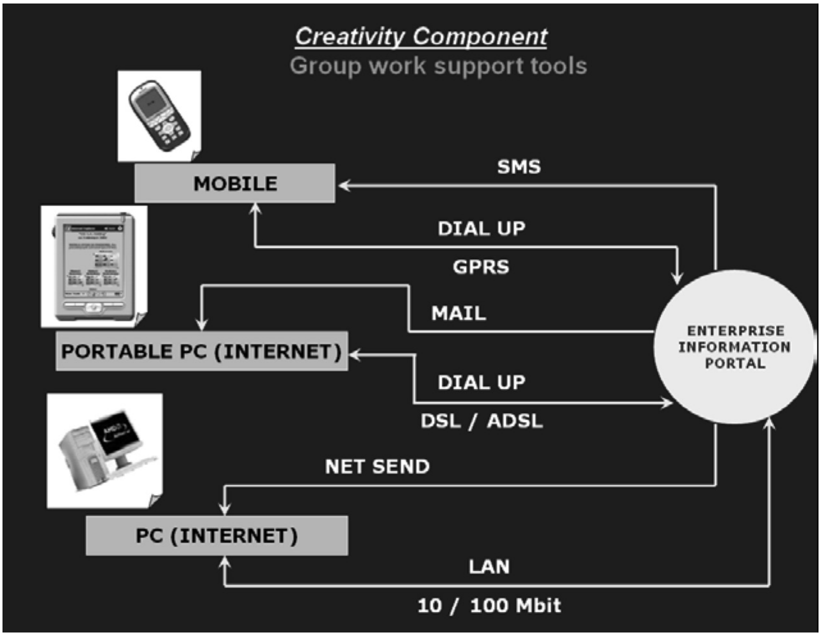


Figure 7. Group work support tools

Source: own elaboration.

- SWOT analysis support tools (Figure 8),

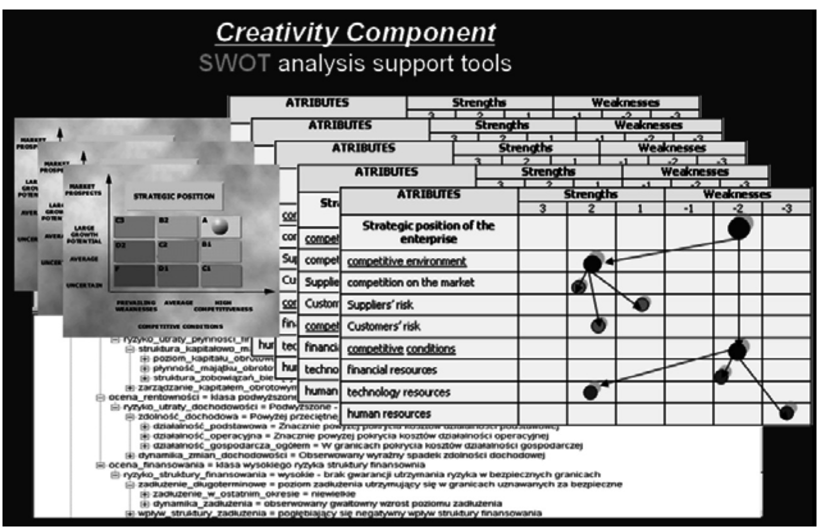


Figure 8. SWOT analysis support tools

Source: own elaboration.

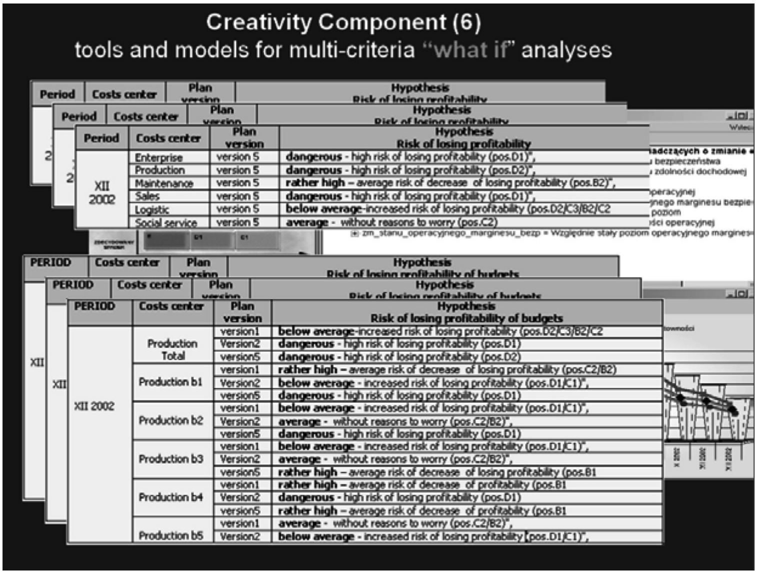


Figure 9. Tools and models for multi-criteria “what if” analysis

Source: own elaboration.

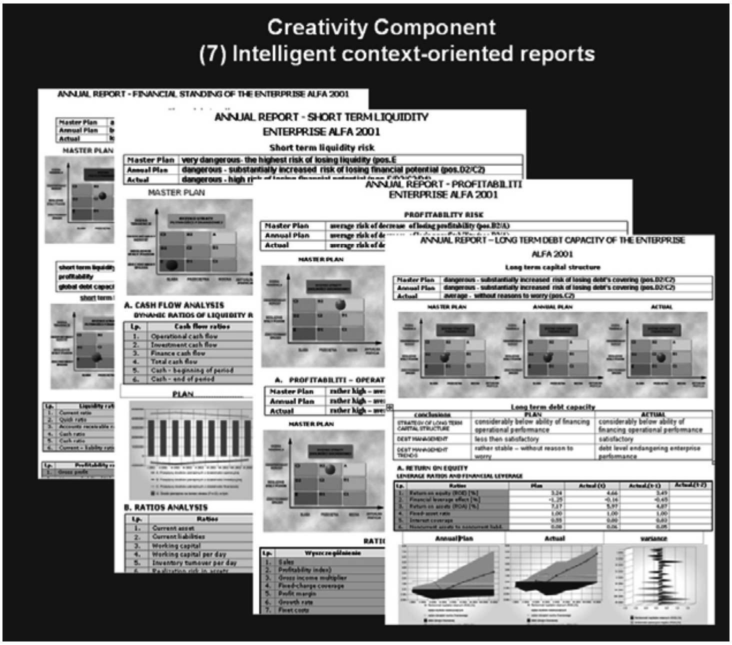


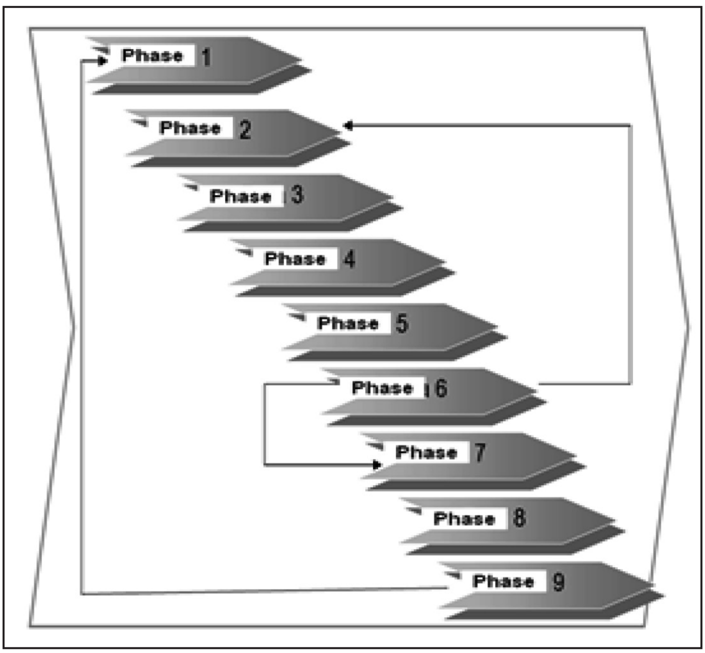
Figure 10. Context-oriented reports

Source: own elaboration.

- tools and models for multi-criteria “what if” analysis (Figure 9),
- context-oriented reports recapitulating the user’s work outcomes; to deliver these outcomes, such reports will make use of e.g. expert systems, presentation graphics, tabular views and layouts [Moore, Chang 1983] (cf. Figure 10).

4. Application of DDMKCC architectural components in capital group management – example

For the purpose of financial strategy performance monitoring in capital groups, the decision making process could be, drawing on H. Simon’s classical description, conceptualized as a nine-phase process. The process begins by setting short-term financial targets for the groups’ daughter companies and concludes with making any necessary amendments to budgetary plans and, eventually, preparing a new budget (cf. Figure 11). Among business management processes (particularly in capital



Phase 1 – Setting budget targets for subsidiary companies; Phase 2 – Budget modeling in daughter companies; Phase 3 – Management-led financial consolidation of budgets; Phase 4 – Analysis of threats and opportunities to performance of consolidated group budget; Phase 5 – Analysis of strengths and weaknesses of subsidiary companies’ budgets; Phase 6 – Budget negotiations; Phase 7 – Identifying KPIs/CSFs for subsidiary companies’ and group’s budgets; Phase 8 – Monitoring performance for deviations from plan, early warning of threats; Phase 9 – Budget validation and control.

Figure 11. Phases of the budget consolidation process in a capital group

Source: own elaboration.

groups), this is one of the key sub-processes of strategic management, accounting for the effective monitoring of strategic goal performance, since Phase 1 of the process is directly linked to a company's strategic goals and constitutes an operational tool for strategy implementation and performance control. It should be added that budget consolidation is perceived as the primary process, while operational budgeting processes are seen as secondary.

- Setting budget targets

Within the process being discussed, operational budgetary targets are defined as partial targets (i.e. annual) prescribed by the capital group's overarching strategy. These goals, taking the form of financial, operating, etc., parameters are subsequently, at the stage of subsidiary budget modeling, disaggregated into periods such as months and/or quarters (Phase 2). Subsidiary budgets and, as a consequence, the master budget, too, are evaluated in respect of target performance and their impact on the group's overall financial result.

- Budget modeling in subsidiary companies

There are usually multiple alternative paths to pursue budgetary targets imposed by, or negotiated with, the parent company. The modeling phase is aimed at developing such a budget variant that, on the one hand, leads to effectively achieving the target and, on the other, is "realistic" and "executable" for the subsidiary. To a large extent, this phase informs budget negotiations (as long as the budgetary process includes such a phase), providing arguments supporting each party's position during budget preparation.

- Financial consolidation of budgets

Data sets describing the financial budget of a subsidiary company have to, even at the budget preparation stage, allow for the exclusion of consolidation-related events. Budgets adopted for subsidiary companies make up a frame of reference for the appraisal of deviations. The capital group's consolidated budget, in turn, provides a basis for the assessment of risks to the execution of strategic projects.

- Analysis of threats and opportunities to performance of consolidated group budget

This phase consists in analyzing the group's consolidated budget for perceived opportunities and threats for the performance of organizational strategic objectives. Instruments used in risk assessment and measurement include sensitivity analyses and simulations based on the distribution of the subsidiary companies' key market and operational-financial variables (concentration curves, portfolio analyses). Just as important is the internal benchmarking of daughter companies and/or key business processes within the capital group. Benchmarking analyses are carried out through monitoring across economic activity areas and through subsidiary companies' rankings within each area of activity. As a result, aggregate reports are compiled illustrating the performance of specific subsidiaries against a number of criteria, alongside expert evaluations of the threats and opportunities in each area. The impact of changes in the position of a company or group (e.g. divisions) on the capital group's final financial position in the market is also examined. The risk of the group's financial position is estimated by assessing the budget impact of weighted deviations in the companies' ranking positions being monitored.

- Analysis of strengths and weaknesses of subsidiary companies' budgets

Each company's budget must be assessed with regard to its impact on the groups' consolidated budget. Owing to budget negotiations, the parent company should be able to determine risks to the performance of a subsidiary budget and to prepare emergency scenarios. As a result, each company is classified into a risk category and assessed in at least two perspectives: vis-à-vis its expected contribution toward the achievement of the group's targets, and in terms of its historical position within the capital group.

- Budget negotiations

Budget negotiations result in the generation of multiple budget variants. It is assumed that multiple scenarios can be adopted for each any budget (financial plan), known as best-case, worst-case, average, etc.

- Identifying early warning signals (KPIs/CSFs) for subsidiary companies' and group's budgets

For each area and/or company, the so called early warning signals are defined – the key performance indicators that allow the most effective detection of threat symptoms. To ensure comparability, the signals must make up a logical system where cause-effect relationships are established between elements at the highest aggregation level, identical for each constituent company. The signals permit the construction of the most synthetic company ranking in each of the key business areas. For each signal, relevant statistical measures are estimated based on historical data and forecasts: mean values, quartiles, spreads, etc, and on expert opinions. Each early warning signal must be then assigned the so called activation threshold that triggers a warning. The thresholds are defined at the level of a company's business activity areas (e.g. income capability, human resources management, etc.) as well as for the aggregate indicators which are deemed critical to the company's operations. The activation thresholds can be thus either quantitative or qualitative.

- Monitoring performance for deviations from plan, early warning of threats

Within the proposed approach, monitoring and warning appear as parts of the most complex phase of the budget consolidation process (and therefore can even be seen as an autonomous sub-process). On detection of opportunities and threats relating to budget performance, diagnostic procedures can be triggered to anticipate the effects that the symptoms may have in subsequent periods. This information is then used to undertake preventive or corrective measures. Each area of business activity, as well as each constituent company, is regarded as a system component which contributes value to the capital group. Hence the Economic Value Added (EVA) mode becomes a fundamental tool for the modeling of the capital groups' development strategy.

The use of each type of tool was examined following the observation of the subsequent stages of budget planning and budget control processes (monitoring deviations from targets) in capital groups – cf. Table 11.

Table 11. Creativity support tools most heavily used by capital groups within budget planning and control processes to monitor deviations from plan

	Process	Intelligent context-based assistance for problem solving	Multi-dimensional OLAP data base viewer	Group work support tools	SWOT analysis support tools	"What if" analytical models	Intelligent context-sensitive reports
1	setting budget targets for subsidiary companies	xxx	–	x	–	x	x
2	budget modeling in daughter companies	x	xxx	x	–	xxx	xx
3	management-led consolidation of financial budgets	x	xx	–	–	–	x
4	analysis of threats and opportunities to performance of consolidated group budget	x	xx	x	xxx	xxx	xxx
5	analysis of strengths and weaknesses of subsidiary companies' financial budgets	x	xxx	x	xxx	xxx	xxx
6	budget negotiations	–	xx	xxx	–	xxx	x
7	identifying KPIs/ CSFs for subsidiary companies' and group's budgets	xx	x	x	–	xxx	xxx
8	monitoring deviations from plan, early warning of potential threats	xx	xx	xx	–	xxx	xxx
9	validation and control of financial budgets	xx	xxx	xx	xx	xxx	xxx

Source: own elaboration.

Importantly, we perceived the necessity to make DSS capable of fast and easy integration with specialized external solutions designed to support certain creative problem solving techniques (e.g. brainstorming or morphology analysis).

5. Conclusions

Researchers dealing with computerized decision support are exhibiting a growing interest in integrating individual and domain-specific insights and building common theoretical, methodological and applicational frameworks that can sustain systemic thinking.

In the long run, thinking in terms of software architectures facilitates DSS development and maintenance. A holistic view fosters diverse applications, iterative development and, in particular, a distinctive approach, perhaps unique to DSS, whereby systems are developed in response to changes in the decision space. Many DSS have evolved from a data-oriented system and modeling a specific domain, e.g. financial control, which became a starting point, then arousing broader interest in the system itself and inspiring innovative efforts at large. Next, there arises a need for group work and creativity support.

By investigating across multiple aspects, the ways in which specific DDMKCC model components are used in the practice of making business decisions, we have identified the key determinants of an effective development context for computerized decision support systems. The paper presents research findings which encourage the belief that the further development of context-dependent DSS design meta-methodology should be approached from the system designer's perspective.

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ROZWÓJ BADAŃ NAD METODYKĄ METAPROJEKTOWANIA SWD

Streszczenie: Podejście architekturalne wyznacza jedną ze ścieżek rozwoju, jakimi może podążyć wprowadzona do dziedziny SWD przez Moore'a i Changa metodyka metaprojektowania. Większość rozważań nad architekturą SWD wychodzi od paradygmatu DDM (dane-dialog-modelowanie) (lub się do niego odnosi), sformułowanego przez Sprague'a i Carlsona. Badania prowadzone przez autorów w latach 80. XX wieku na rzecz kilku polskich przedsiębiorstw wskazały na potrzebę poszerzenia tego paradygmatu. Proponowane przez nich rozwiązanie zmierza zatem do wzbogacenia metodyki metaprojektowania SWD. Celem artykułu jest też zaprezentowanie wyników autorskich badań nad rozwiązaniem, które od ponad dziesięciolecia funkcjonuje w dużych przedsiębiorstwach i grupach kapitałowych.

Słowa kluczowe: SWD, paradygmat DDM, metodyka projektowania, architektura oprogramowania, studium przypadku.